

EO-1 ICD-47  
Draft Issue  
December 18, 1997

**EO-1  
X-BAND PHASED ARRAY  
ANTENNA SYSTEM  
INTERFACE CONTROL DOCUMENT  
(ICD)**



National Aeronautics and  
Space Administration \_\_\_\_\_

Goddard Space Flight Center \_\_\_\_\_  
Greenbelt, Maryland

# **Interface Control Document**

for the

**New Millennium Project  
Earth Orbiter-1 (EO-1)  
X-Band Phased Array Antenna System  
18 December 1997**

**NASA Goddard Space Flight Center**

**Summary:**

The Interface Control Document for the New Millennium Project X-Band Phased Array Antenna (XPAA) provides a definition of all functional, physical, and electrical characteristics of the XPAA that impact the Earth Observer-1 (EO-1) spacecraft on which it will be installed. The interface definition in the ICD is designed to ensure that equipment and software delivered by The Boeing Company will operate properly when installed on the EO-1 spacecraft, will meet the requirements for which it was designed, and will not adversely affect any aspect of the EO-1 spacecraft operations.

## TABLE OF CONTENTS

	Page
1. GENERAL.....	6
1.1 Scope and Purpose.....	6
1.2 Antenna Subsystem Overview.....	6
1.3 Applicable Documents.....	6
2. SYSTEM INTERCONNECT DIAGRAM.....	8
3. MECHANICAL INTERFACE.....	9
3.1 General.....	9
3.2 Antenna Envelope.....	9
3.3 Antenna Footprint and Fastener Requirements.....	9
3.4 Antenna Mounting Requirements .....	10
3.5 Antenna Mass and Center of Mass.....	10
4. THERMAL INTERFACE.....	11
5. ELECTRICAL INTERFACE.....	12
5.1.General.....	12
5.2.Electrical Block Diagrams.....	12
5.3.RF Interface.....	13
5.4.DC Power Requirements.....	14
5.5.Communications Interface.....	14
5.6.Cabling interface.....	15
5.7.EMI/RFI.....	15
5.8.List of Connectors.....	15
6. SOFTWARE INTERFACE.....	17
7. VALIDATION INTERFACE.....	18
7.1 List of Validation Functions.....	18
7.2 Implementation of Validation Functions.....	18
7.2.1.Array Voltages.....	18
7.2.2.Array Currents.....	18
7.2.3.Temperature Measurements.....	19
7.2.4.Phase Bit Verification.....	19
7.3 Range of Validation Functions.....	19
7.4 Telemetry Frequency.....	20

## LIST OF FIGURES

		Page
Figure 2.1	System Interface Diagram.....	8
Figure 3.2.1	Physical Envelope of the Antenna.....	9
Figure 3.3.1	Antenna Footprint.....	10
Figure 5.2.1	RSN Electrical block diagram.....	12
Figure 5.2.2	Array Block Diagram.....	13
Figure 5.3.1	RF Allocations.....	14
Figure 7.2.1	Antenna Current and Voltage Measurement Network.....	18
Figure 7.2.3	Temperature Measurement Interface.....	19

## LIST OF TABLES

Table 5.7.1	Antenna Connections.....	15
Table 5.7.2	Connector J6 Pin-Outs.....	15
Table 5.7.3	Connector J7 Pin-Outs.....	16
Table 5.7.4	Connector J8 Pin-Outs.....	16
Table 7.3	Measured Parameter Values and Ranges.....	20

## ACRONYMS AND ABBREVIATIONS

ASIC	Application Specific Integrated Circuit
CMOS	Complementary Metal Oxide Semiconductor
DC	Direct Current
D&SG	Defense & Space Group (Boeing)
COTS	Commercial Off-The-Shelf
EO-1 S/C	Earth Observer-1 Spacecraft
EIRP	Effective Isotropically Radiated Power
ESN	Essential Services Node
ICD	Interface Control Document
LVPC	Low Voltage Power Supply
MCM	Multi-Chip Module
MMIC	Monolithic Microwave Integrated Circuit
NASA	National Aeronautics and Space Administration
NMP	New Millennium Project
RF	Radio Frequency
RSN	Remote Services Node
SOW	Statement of Work
SSO	Space Systems Operation (Litton Amecom)
V	Volts
XPAA	X-Band Phased Array Antenna
WARP	Wideband Advanced Recorder Processor

## **1. GENERAL**

This ICD contains data and drawings required to define the interface characteristics of the X-Band Phased Array Antenna System that will be mechanically, functionally and electrically integrated with the Earth Observer-1 Spacecraft.

### **1.1. Scope and Purpose**

The ICD will contain all software, hardware (mechanical), thermal, electrical power, RF signal, logic or control signal, telemetry signal, data signal and operational interfaces of the XPAA with the EO-1 spacecraft. Included are the ESN and RSN components.

### **1.2. Antenna Subsystem Overview**

The X-Band phased array antenna comprises 64 active radiating elements each with an independent phase controller and power amplifier allowing electronic steering of the antenna beam. Element phases are calculated to point the beam at the commanded elevation and azimuth by an RSN provided by Litton Amecom. Telemetry and commands are transmitted to the antenna over a dual MIL-STD 1773 fiber optic data bus, and 8.225 GHz RF excitation is supplied by the WARP via a coaxial cable. The data rate is 105Mbps.

The advantage of an electronically steered antenna for small satellite applications, where platform stability is important, is that no reaction torque compensation is needed during a communications pass allowing the simultaneous acquisition of precision optical data.

### **1.3. Applicable Documents**

- a. **NASA Document 737-EO1-RSD-XPAA**, "Performance Specification and Design Requirements for the New Millennium Program Earth Observer-1, X-Band Phased Array Antenna", released April 1, 1997
- b. **NASA Document 737-EO1-SOW-XPAA**, "Statement of Work for the New Millennium Program Earth Observer-1, X-Band Phased Array Antenna", released April 4, 1997

- c. **Swales Aerospace, Inc. Internal Memo, "EO-1 X-Band Antenna Environmental Criteria"**, George Hinshelwood to Mike Cully, EO-1 Project Manager/Swales Aerospace, released March 24, 1997, transmitted to Gary Miller, X-Band/Mechanical Lead/Boeing Company
- d. **MIL-STD-461C**, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference (Notice 1)
- e. **MIL-STD-462**, Measurement of Electromagnetic Interference Characteristics
- f. **MIL-STD-1773B**, Fiber Optics Mechanization of an Aircraft Internal Time-Division Command/Response Multiplex Data Bus
- g. **NASA Document ICD-735-2827**, "Essential Services Node hardware Specification (Revision 2.0)"
- h. **Litton Drawing No. 184622**, "Chassis Assembly, LWH-14-.050"
- i. **Litton Document ICD-xxx-xxx**, "X-Band Exciter to Memory Interface Control Card"
- j. **Swales Document XXX-XXX**, "Cable ICD"

## 2. SYSTEM INTERFACE DIAGRAM

An interconnect diagram is provided to show the system level interconnects for RF excitation, fiber optic control and telemetry signals, and DC power. A service connector for software loading, and a test connector for testing during integration are also shown. Electrical and signal characteristics, and cabling are further defined in Section 5

Figure 2.1 shows the system interface connections between the antenna and the WARP, the fiber optic star coupler, and the 28 V power supply.

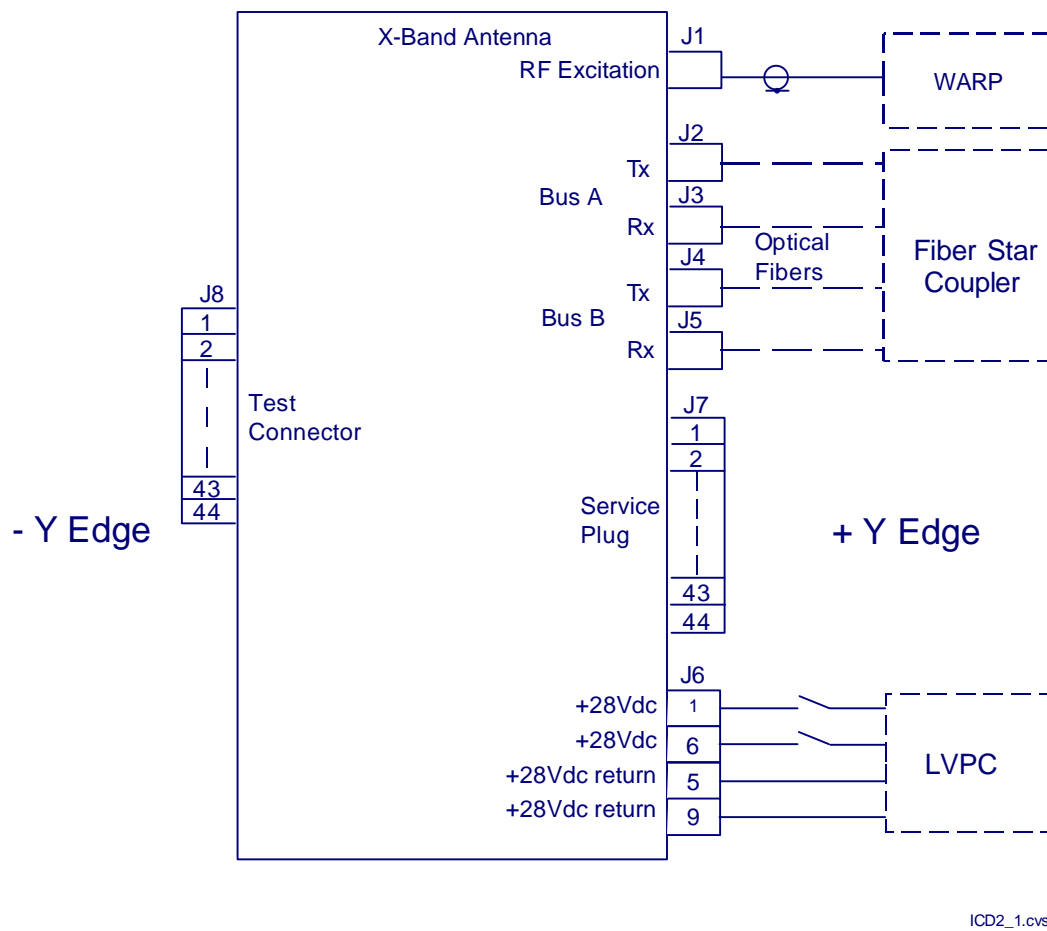


Figure 2.1 System Interface Diagram

### 3. MECHANICAL INTERFACE

#### 3.1. General

The antenna enclosure is a two level structure. The 64 radiating elements and the high wattage dc to dc converters for the antenna 5V power are located on the upper level, and an RSN controller board is located on the lower level. The lower level of the enclosure is geometrically identical to one slot of the Litton Chassis (Litton drawing No. 184622) permitting the generic RSN board to be accommodated without any mechanical change to the basic RSN.

#### 3.2. Antenna Envelope

Figure 3.2.1 shows the physical envelope of the antenna. The RF excitation input, the service connector, and the fiber optic connectors are located on the positive Y direction face, and the test connector on the negative Y direction face.

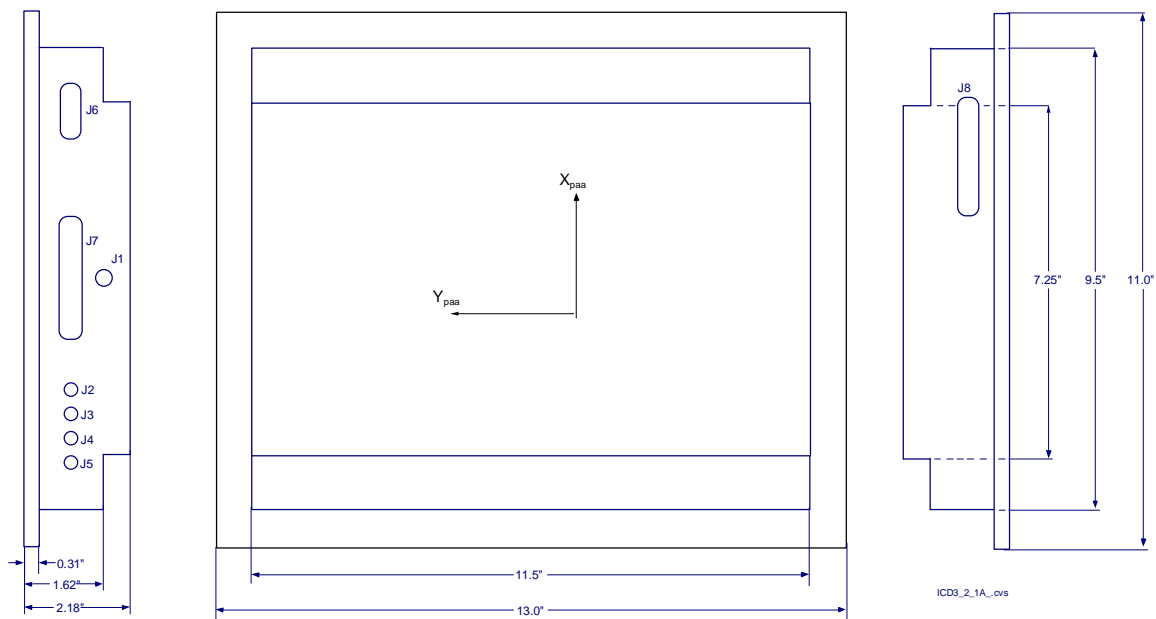


Figure 3.2.1 Physical Envelope of the Antenna

#### 3.3. Antenna Footprint and Fastener Requirements

Figure 3.3.1 shows the mechanical footprint of the antenna. The antenna is secured to the mounting plate by 8 NES 1578 ¼-28 threaded fasteners.

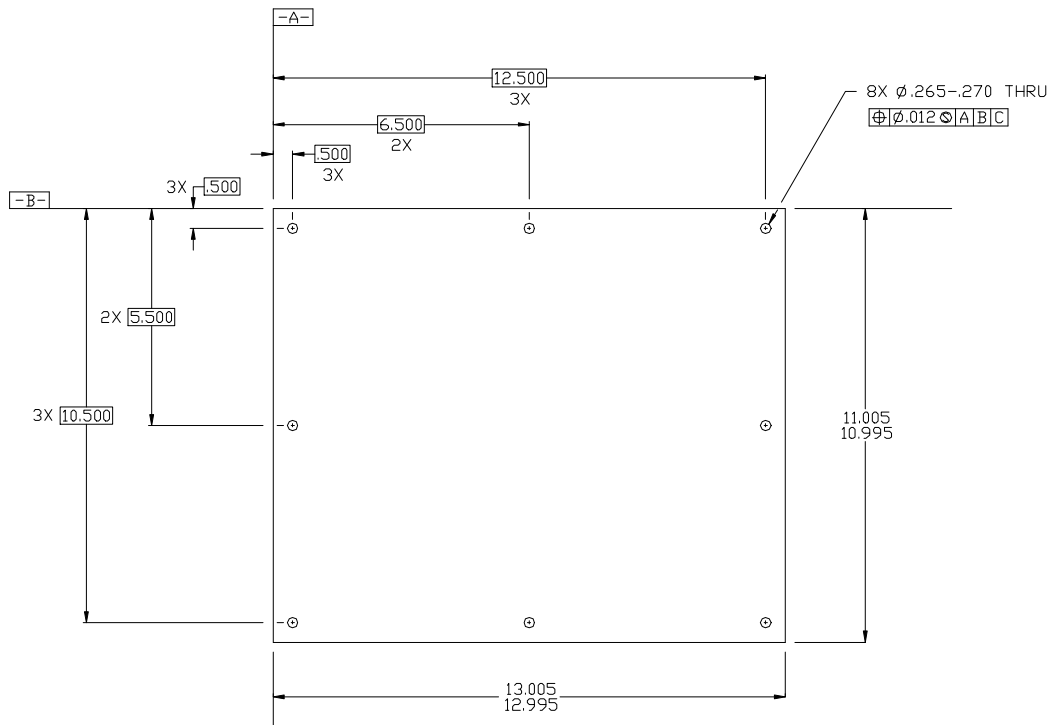


Figure 3.3.1 Antenna Footprint

### 3.4. Antenna Mounting Requirements

A sheet of xxx Co-Therm should be placed between the antenna and the mounting plate, and the 1/4-28 fasteners torqued to 91 ins-lbs.

### 3.5. Antenna Mass and Center of Mass

TBD

#### **4. THERMAL INTERFACE**

Power dissipated by the antenna will range from 40 to 56 W depending upon the final MMIC configuration. Radiated heat input or loss during operation and transient behavior are TBD.

## 5. ELECTRICAL INTERFACE

### 5.1. General

The antenna comprises a 64 element array, and an RSN board. With the exception of the antenna modules, all electrical and electronic components are mounted on the RSN board.

### 5.2. Electrical Block Diagrams

Figure 5.2.1 shows the RSN electrical block diagram.

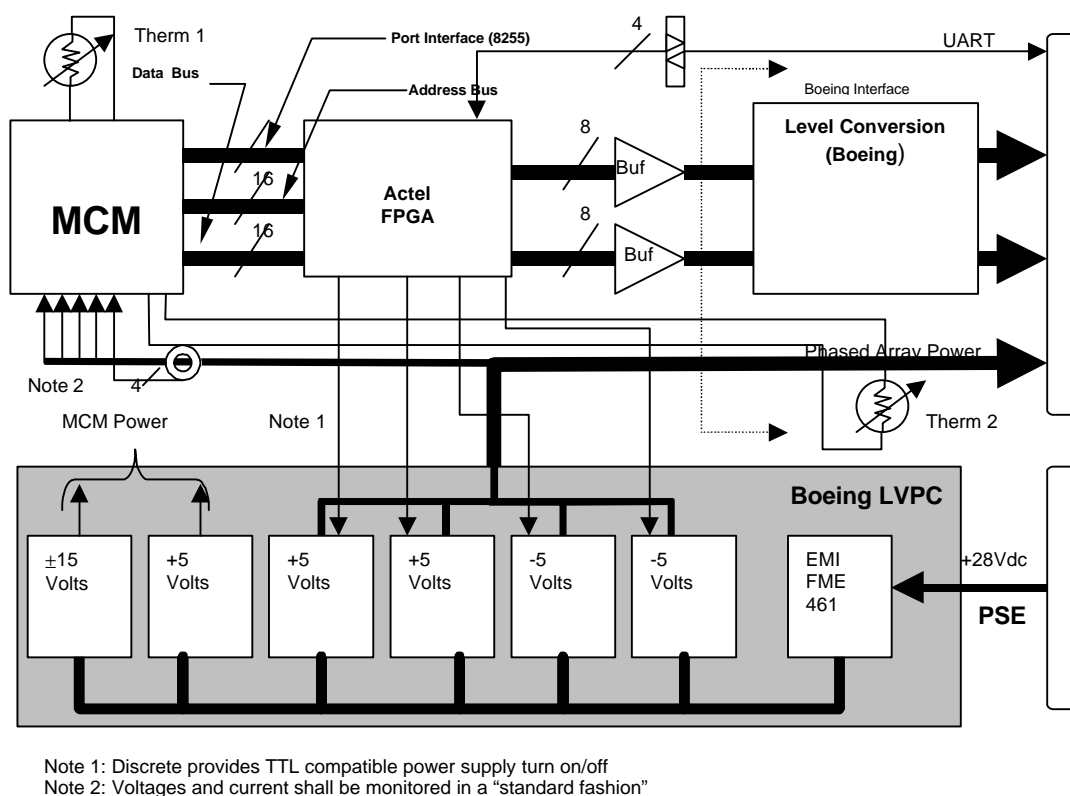


Figure 5.2.1 RSN Electrical Block Diagram

Support electronic components, a FPGA, level translation (TTL to -5 to 0V) integrated circuits, and six dc-to-dc power converters are located on the RSN board. Four low power converters and an RFI filter are located on the "A" side of the RSN board, and two 30 W converters are located on the "B" side of the board..

December 18, 1997

Figure 5.2.2 shows the array block diagram. The array is divided into two sections for redundancy. The link margin is such that in the event of the failure of one side of the array, the link will still be closed.

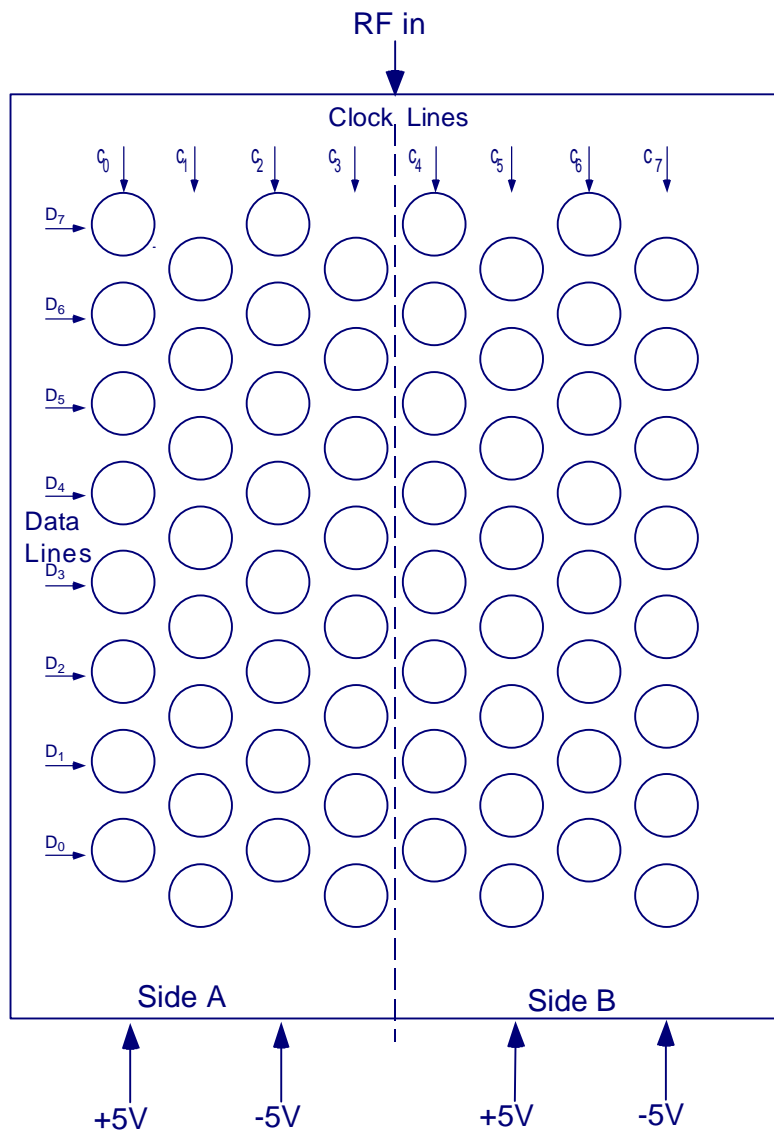


Figure 5.2.2 Array Block Diagram

### 5.3. RF Interface

Figure 5.3.1 shows the system RF allocations. The excitation is described in the exciter specification Litton Doc. Xxxx. The input interface connector is a female SMA connector mounted at the center of the +Y face of the enclosure. The connector should be tightened to 6 ins-lbs.

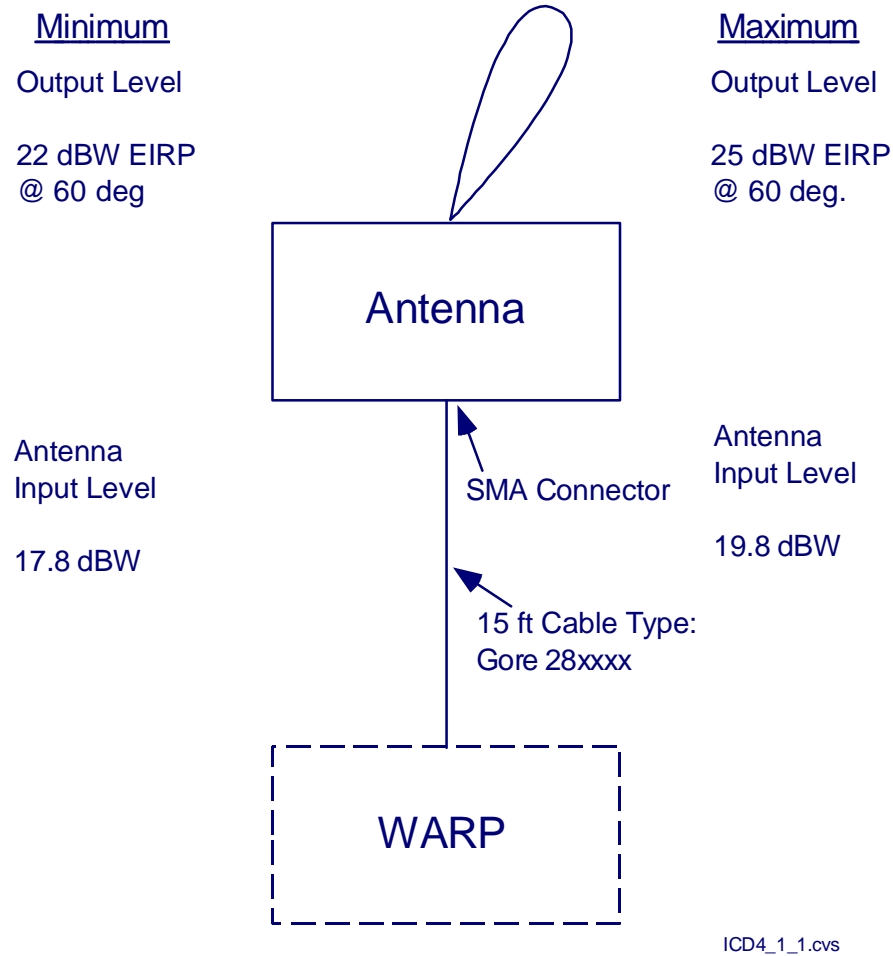


Figure 5.3.1. R.F. Allocations

#### 5.4. DC Power Requirements

The nominal dc power requirement is 44 W with a worst case of 60 W. The antenna will operate over an input voltage range of 21 to 35 V with source impedance, transients, and ripple in accordance with the statement of work. The interface connector is 311P 409-1P and the pin assignment is shown in Table 5.7.2

#### 5.5. Communications Interface

Command, pointing, and telemetry information is transmitted over a dual 1773 bus. The protocols are described in RSN ICD Document No. AM149-0050(155).

## 5.6. Cabling Interface

The antenna cabling interface is described in the cable harness ICD Swales document No. xxxx

## 5.7. EMI/RFI

The antenna will satisfy conducted and radiated emission and conducted and radiated susceptibility requirements as specified in the SOW.

## 5.8. List of Connectors

The antenna external interfaces are implemented with the connectors listed in Table 5.7.1. Connector pin outs are listed in Tables 5.7.2 - 5.7.4.

Table 5.7.1 Antenna Connectors

Connector Number	Connector Type	Pins Used	Description
J1	SMA	-	RF Excitation Input
J2	FC	Fiber	1773 Bus A Input
J3	FC	Fiber	1773 Bus A Output
J4	FC	Fiber	1773 Bus B Input
J5	FC	Fiber	1773 Bus B Output
J6	311-P409-1PB-15 9-Pin D-Type Male	1,5,6,9	28V Input Power
J7	311-P407-3S-B-15 44-Pin D-Type Female	TBD	Service Connector
J8	Female TBD	TBD	Test Connector

Table 5.7.2 Connector J6 Pin-Outs

Pin Number	Signal	Description
1	28V in A	Switched +28 V Power from LVPC
5	28V Return A	28 V Power Return
6	28V in B	Switched +28 V Power from LVPC
9	28V Return B	28 V Power Return

Table 5.7.3 Connector J7 Pin-Outs

	<b>TBD</b>	

Table 5.7.4 Connector J8 Pin-Outs

	<b>TBD</b>	

## **6. SOFTWARE INTERFACE**

The software requirements are described in the Software Specification Document No XPAA-093

## 7. VALIDATION INTERFACE

### 7.1. List of Validation Functions

On orbit validation functions are described in the SOW. Housekeeping parameters recorded are voltages and currents supplied by each dc-to-dc converter, and the temperatures of the array baseplate and the ESN lid. Computation of the correct phases for a given  $\theta$  and  $\phi$  is verified by recording the 64 4-bit phase values transmitted to the 8 x 8 array together with the values of  $\theta$  and  $\phi$  received from the ACU.

### 7.2. Implementation of Validation Functions

#### 7.2.1. Array Voltages

The +5V and -5V voltages supplied to each side antenna array are obtained by measuring the voltage at the array side of the resistor in series with dc to dc converter as shown in Figure 7.2.1

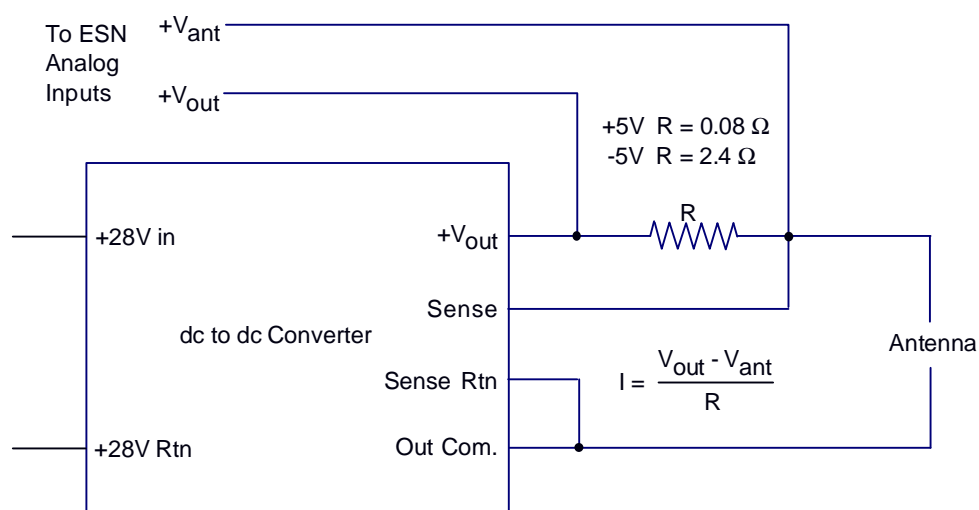


Figure 7.2.1 Antenna Power Supply Voltage Current Measurement Network

#### 7.2.2. Array Currents.

The +5V and -5V currents supplied to each side antenna array are obtained as shown in Figure 7.2.1 by measuring the voltage drop across a resistor in series with the dc to dc converter and the antenna. The series resistors are chosen to provide a 2% precision current measurement assuming 0V to +10V, and +10V to -10V analog voltage ranges for the +5V and -5V lines respectively, and 12-bit A to D conversion.

### 7.2.3. Temperature Measurements

The temperatures of the center of the array pressure plate and the ESN lid will be measured using thermistors as shown in Figure 7.2.3.

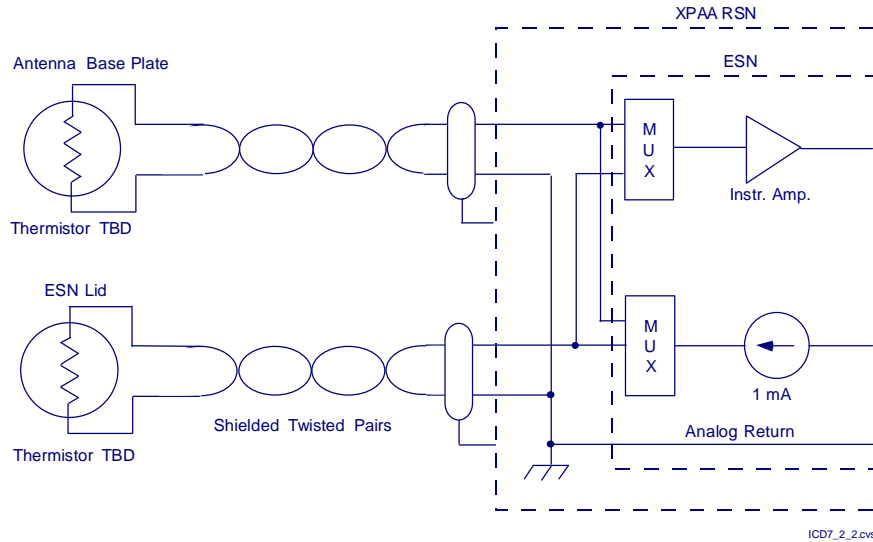


Figure 7.2.3 Temperature Measurement Interface

### 7.2.4. Phase Bit Verification

The contents of the memory array containing the 64 4-bit phase values (256 bits) will be retrieved and telemetered together with the commanded pointing angles. Further information will be given in the internal software description.

## 7.3. Ranges of Validation Functions

The expected values and acceptable ranges of the measured parameters are given in Table 7.3. The expected values are preliminary and will be finalized after final integration and testing has been performed. Possible failure modes that will be detected are also given.

Table 7.3 Measured Parameter Values and Ranges

Parameter	Expected Value	Acceptable Range	Failure Mode Identified
+5V Antenna Side A	5.0 V	+/- 0.1 V	Power supply/catastrophic hardware failure
+5V Antenna Side B	5.0 V	+/- 0.1 V	Power supply/catastrophic hardware failure
-5V Antenna Side A	-5.0 V	+/- 0.1 V	Power supply/catastrophic module failure
-5V Antenna Side B	-5.0V	+/- 0.1 V	Power supply/catastrophic module failure
Pos. Current Side A	3.0 to 3.9 A*	+/- 0.3 A <sup>+</sup>	Module failure
Pos. Current Side B	3.0 to 3.9 A*	+/- 0.3 A <sup>+</sup>	Module failure
Neg. Current Side A	-90 to -130 mA*	+/- 10 mA <sup>+</sup>	Module failure, SEL
Neg. Current Side B	-90 to -130 mA*	+/- 10 mA <sup>+</sup>	Module failure, SEL
Pressure Plate Temp.	10°C above cold plate*	+2°C > expected T	Module failure
ESN Lid Temp.	TBD	TBD	TBD
Phase Bit Array	Precalculated values	No variation	RSN failure, software error

#### Notes

\* =Nominal Values. Final values determined after integration and testing

<sup>+</sup> = Will depend upon array temperature

SEL = Single Event Latch-up

#### 7.4. Telemetry Frequency

Housekeeping parameters are measured continuously including during antenna non-operating periods. Housekeeping data and phase values are telemetered to the spacecraft C&DH system every 8 seconds and telemetered to ground upon command.